higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

NOVEMBER EXAMINATION

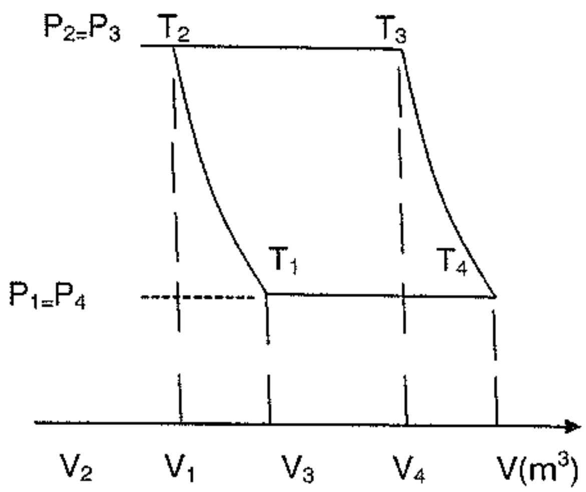
POWER MACHINES N6

18 NOVEMBER 2014

This marking guideline consists of 14 pages.

QUESTION 1

1.1 $\eta_{comp} = \frac{T2' - T1}{T2 - T1} \times 100\%$



$0,85 = \frac{T2' - 288}{515 - 288}$

$T_2' = 480,95$ kPa

$Q_{2\text{-}3} = mCp\,(T_3 - T_2)$

$643 = 1 \times 1\,((T_3 - 515)$

$T_3 = 1158$ K

$P_2 = P_1\,(\frac{T2'}{T1})^{\frac{\gamma}{\gamma-1}}$

$= 103,4(\frac{480,95}{288})^{\frac{1.4}{0.4}}$

$P_2 = P_3 = 622,3$ kPa

$T_4' = T_3\,(\frac{P4}{P3})^{\frac{\gamma-1}{\gamma}}$

$= 1158\,(\frac{103,4}{622,3})^{\frac{0.4}{1.4}}$

$= 693,43$ K

$\eta_{turbine} = \frac{T3 - T4}{T3 - T4'} \times 100\%$

$0,82 = \frac{1158 - T4}{1158 - 693,43}$

$T_4 = 777,06$ K (9)

1.2 $P_2 = P_3 = 622,3$ kPa (3)

1.3 $\frac{T2}{T1} = \left(\frac{P2}{P1}\right)^{\frac{nc-1}{nc}}$

$= \ln\frac{515}{288} = \ln\left(\frac{622,3}{103,4}\right)^{\frac{nc-1}{nc}}$

$\ln 1,7882 = \ln(6,0184)^{\frac{nc-1}{nc}}$

$\ln 1,7882 = \left(\frac{nc-1}{nc}\right)\ln 6,0184$

$nc = \frac{-1,7948}{-1,2078} = 1,48$

$\frac{T3}{T4} = \left(\frac{P3}{P4}\right)^{\frac{ne-1}{ne}}$

$\ln\frac{1158}{777,06} = \ln\left(\frac{622,3}{103,4}\right)^{\frac{ne-1}{ne}}$

$= \frac{(ne-1)}{ne}\ln\frac{622,3}{103,4}$

$0,3989\ ne = 1,7948\ ne - 1,7948$

$ne = \frac{-1,7948}{-1,3959}$

$ne = 1,29$ (6)

1.4 1.2 $Q_{4\text{-}1} = mCp\ (T_1 - T_4)$

$= 1 \times 1\ (288 - 777,06)$

$= -489,06$ kJ/kg (2)

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QUESTION 2

2.1 $BP = \frac{2\pi NT}{60}$

$= \frac{2\pi \times 2000 \times 1.067 \times 15 \times 10}{60}$

= 33,52 Kw

$IP = \frac{BP}{\eta \ mech}$

$= \frac{33{,}52}{0{,}8}$

= 41, 9 kW (6)

2.2 $BT\eta = \frac{BP}{CV \times m/s} \times 100\%$

$0{,}25 = \frac{33{,}52}{44200 \times m/s}$

m = 0, 00303 kg/s

m = 0, 00303 x 60 kg/ min

m = 0, 182 kg/min (4)

2.3 $m_{exhaust} = mf \times 20$ ∴ A/F ratio = 19 :1

= 0,182 x 20

= 3, 64 kg/min

$Q_{exhaust} = m_{exhaust} \times Cp_{exh} \times \Delta T$

= 3, 64 x 1, 05 x 520

= 1 987, 44 kJ/min (4)

2.4 Heat Balance Table

Q fuel (kJ/min)	Q_{in} (kJ/min)		% Supplied
Q= mf x Cv = 0,182 x 44200 = 8044,4 kJ/min	BP = 33,52 x 60	2011,2	25
	Friction = (IP –BP) = (41,9 – 33,52) x 60	502,8	6,25
	Coolant	1987,44	24,71
	Exhaust	1987,44	24,71
	Remainder	1555,52	19,34
8044,4	Total	8044,4	100

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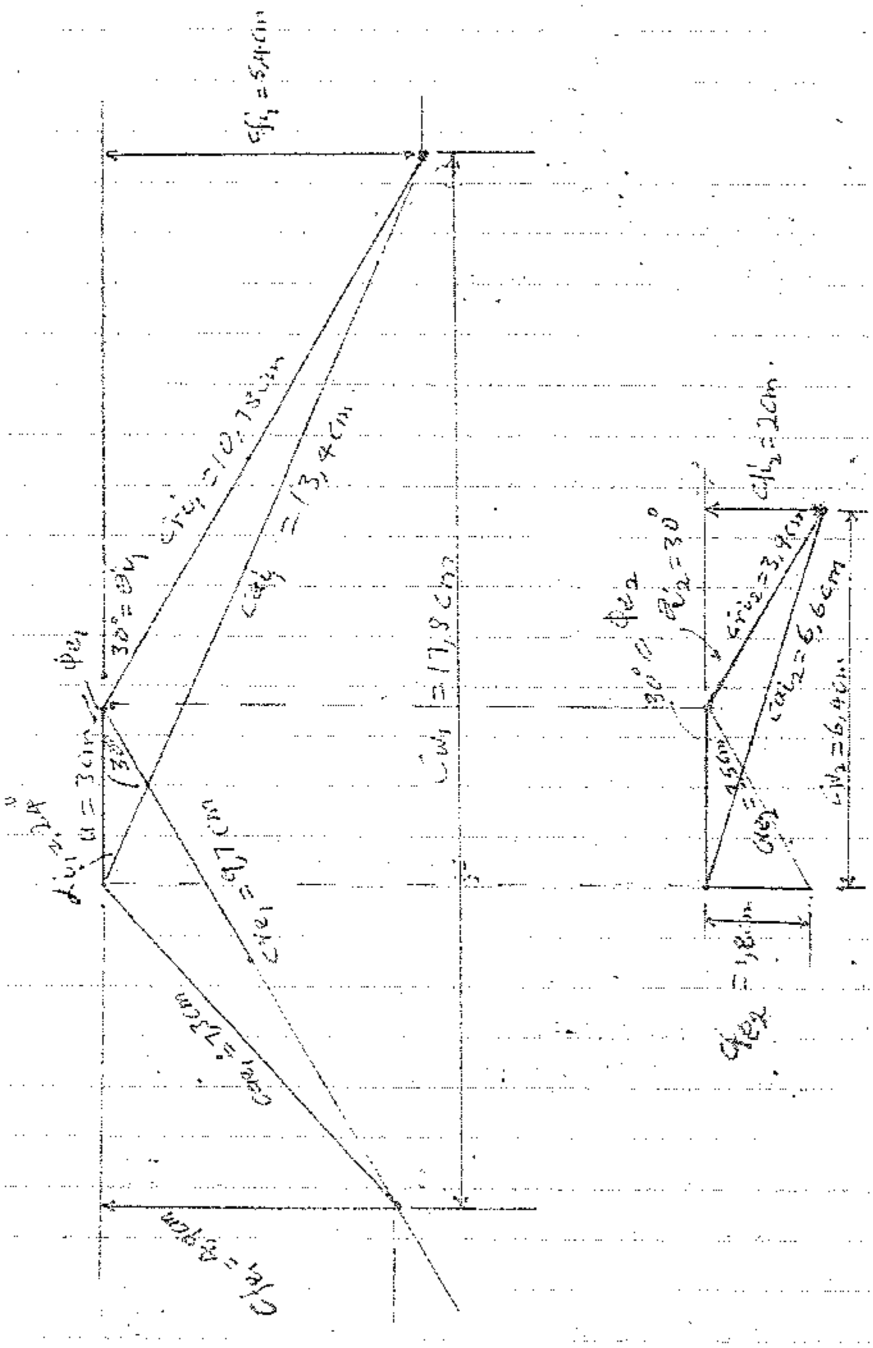
QUESTION 3

3.1 scale = $\frac{500}{13,4}$

= 37, 3 : 1



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3.2 3.2.1 $U = 3 \times 37,3$

$= 112$ m/s (1)

3.2.2 $\alpha i_1 = 24^{\circ}$ (1)

3.2.3 $Cfi_2 = 2 \text{ cm} \times 37,3$

$= 74,6$ m/s (1)

3.2.4 $Cre_2 = 3,5 \text{ cm} \times 37,3$

$= 130,6$ m/s (1)

3.2.5 $P = mu\,(Cw_1 + Cw_2)$

$= 1 \times 112\,(17,8 + 6,4) \times 37,3$

$= 101,09$ kW (3)

3.2.6 $\eta = \dfrac{2u\,(Cw_1 + Cw_2)}{Cai_1^2}$

$\eta = \dfrac{2 \times 112\,(17,8 + 6.4)\,37,3}{(500)^2}$

$= 80,9\ \%$ (3)

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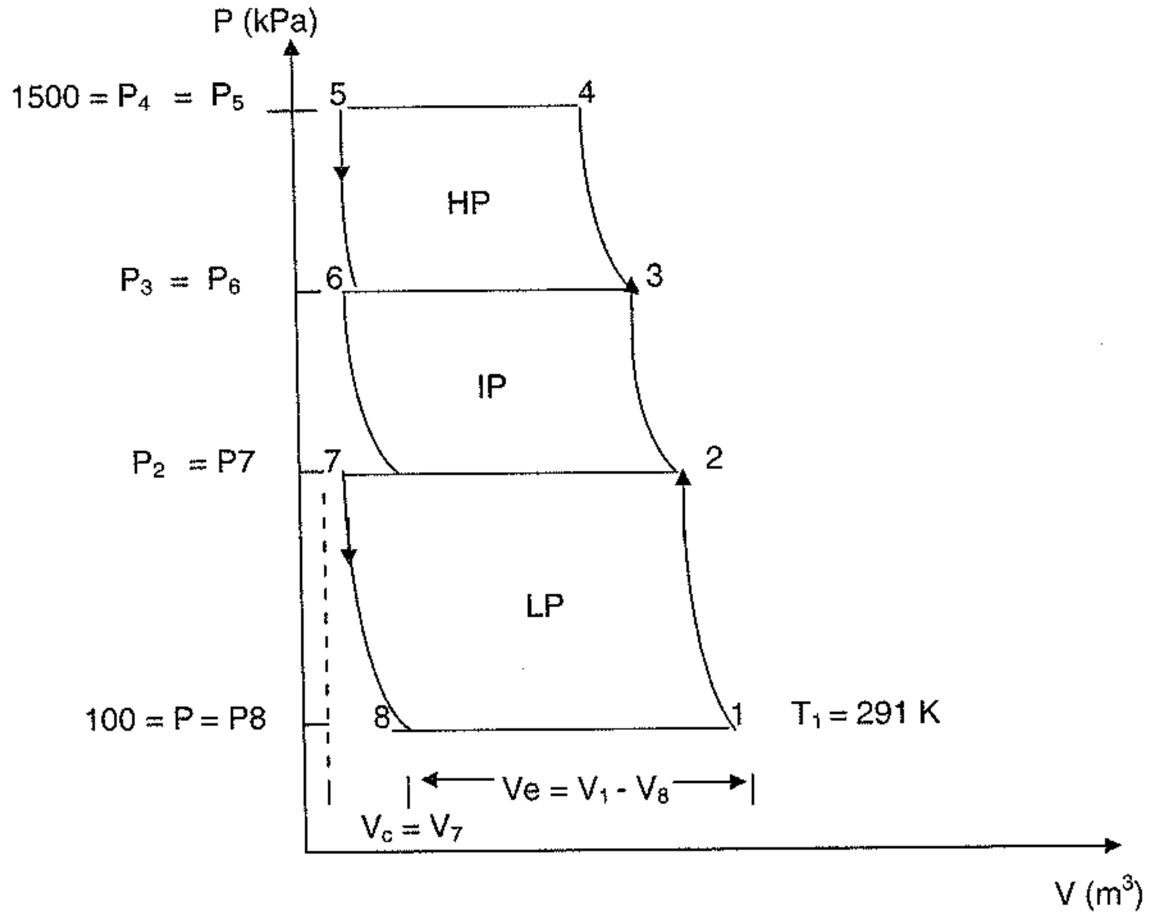
QUESTION 4



4.1 $k = \sqrt[x]{\frac{P4}{P1}} = \sqrt[5]{\frac{1500}{100}} = 2{,}466$

$k = \frac{P2}{P1}$ $\therefore$ $P_2 = 2{,}466 \times 100$
$= 246{,}6$ kPa

$k = \frac{P3}{P2}$ $\therefore$ $P_3 = 2{,}466 \times 246{,}6$
$= 608{,}12$ kPa

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4.2 $2Vs_1 = \frac{\pi}{4}\ d^2 \times L\ = \frac{\pi}{4}(0{,}45)^2 \times 0{,}3 = 0{,}0477\ m^3$

$Vc_1 = 0.05.Vs_1 = 0,\ 05 \times 0,\ 0477 = 0,\ 00239\ m^3$

$V_1 = Vc_1 + Vs_1\ = 0,\ 05.\ Vs_1 + Vs_1 = 1.05\ Vs_1$

$\therefore V_1 = 1,\ 05 \times 0,\ 0477 = 0,\ 0501\ m^3$

$V_8 = V_7\left(\frac{p7}{p8}\right)^{\frac{1}{n}}$

$= 0,\ 00239\ (2{,}466)^{\frac{1}{1{,}3}}$

$= 0,\ 00479\ m^3$

$\therefore Ve_1 = V_1 - V_8$

$= 0,\ 0501 - 0,\ 00479$

$= 0,\ 04531\ m^3$ (5)

4.3 $4.3 T_4 = T_3 = T_2 = T_1\left(\frac{p2}{p1}\right)^{\frac{n-1}{n}}$

$= 291(2{,}466)^{\frac{0{,}3}{1{,}3}}$

$= 358,\ 39\ K$

$V_d = \frac{mRTd}{pd}$

$= \frac{1 \times 0{,}29 \times 358{,}39}{1500}$

$= 0,\ 06929\ m^3$ (5)

4.4 $4.4 W_d = \frac{x\ n\ mRT1}{n-1}\left[\left(\frac{p4}{p1}\right)^{\frac{n-1}{xn}} - 1\right]$

$= \frac{3 \times 1{,}3 \times 1 \times 0{,}29 \times 291}{0{,}3}\left[(15)^{\frac{0{,}3}{3 \times 1{,}3}} - 1\right]$

$= 254,\ 08\ kJ\ /kg$ (5)

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QUESTION 5

5.1 $P_c = P_1\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} = 500\left(\frac{2}{2,4}\right)^{\frac{1,4}{0,4}} = 264,14 \text{ kPa}$

$T_c = T_1\left(\frac{2}{\gamma+1}\right) = 810\left(\frac{2}{2,4}\right) = 675 \text{ K}$ (4)

5.2 $V_c = \frac{RTc}{Pc} = \frac{0,288 \times 675}{264,14} = 0,7359 \text{ m}^3/\text{kg}$

$C_c = \sqrt{2000.Cp(T1 - Tc)}$

$Cc = \sqrt{2000x1,008(810 - 675)}$

$Cc = 521,69 \text{ m/s}$

$A_c = \frac{mVc}{Cc} = \frac{1x0,7359}{521,69} = 0,00141 \text{ m}^2/\text{kg} = 1\,410 \text{ mm}^2/\text{kg}$ (6)

5.3 $T_2' = T_1\left(\frac{P2}{P1}\right)^{\frac{\gamma-1}{\gamma}} = 810\left(\frac{143}{500}\right)^{\frac{0,4}{1,4}} = 566,45 \text{ K}$

$\eta = \frac{T1 - T2}{T1 - T2'} = \frac{810 - T2}{810 - 566,45} = 0,92$

$\therefore T_2 = 585,93 \text{ K}$ (4)

5.4 $V_2 = \frac{RT2}{P2} = \frac{0,288 \times 585,93}{143} = 1,1801 \text{ m}^3/\text{kg}$

$C_2 = \sqrt{2000.Cp(T1 - T2)} = \sqrt{2000x1,008(810 - 585,93)}$

$\therefore C_2 = 672,10 \text{ m/s}$

$A_2 = \frac{mV2}{C2} = \frac{1x\,1,801}{672,1} = 0,00268 \text{ m}^2/\text{kg}$

$= 2\,680 \text{ mm}^2/\text{kg}$ (6)

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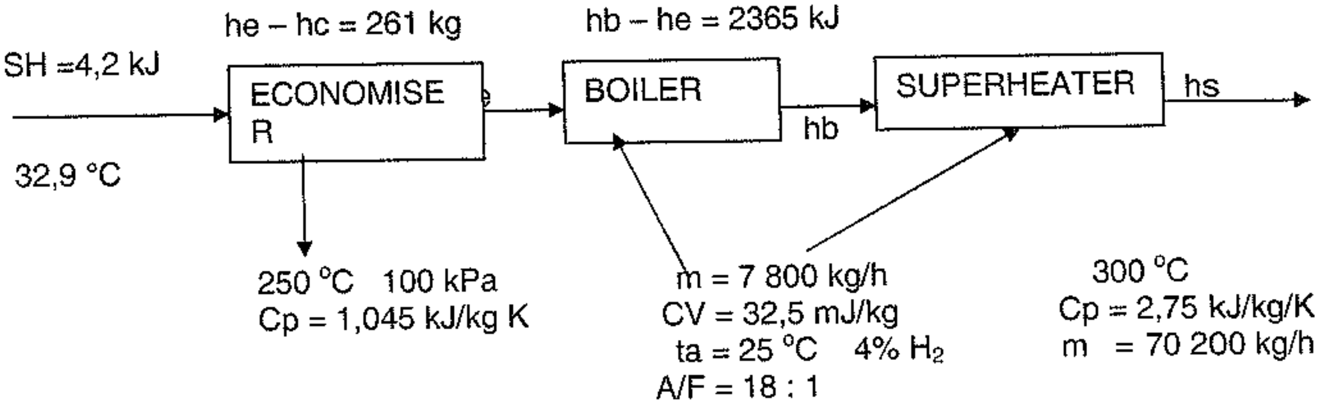
QUESTION 6



ms/kg of fuel $= \frac{70200}{7800}$ = 9 kg

$h_e - h_c = \frac{2349}{9} = 261$ kJ

$h_b - h_e = \frac{21287}{9} = 2\,365$ kJ

6.1 @ 2 000 kPa and 300° C: h_s = 3025 kJ/kg

@ 3 000 kPa and 300° C: h_s = 2 995 kJ/kg
= 30 kJ/kg

A 1000 kPa will decrease the enthalpy by 30 kJ/kg

A 500 will decrease the enthalpy by 15 kJ/kg

The superheat enthalpy at 2500 kPa will be 3025 – 15 = 3010 kJ/kg

$$\eta_{plant} = \frac{ms(hs - hc)}{m_f \times CV} = \frac{70200(3010 - 4{,}2 \times 32{,}9)}{7200 \times 32500}$$

$$= 79{,}53\%$$ (5)

6.2 $h_e - h_c = 261$

$h_e = 261 + hc = 261 + 4{,}2 \times 32{,}9$

$= 399$ kJ/kg

$h_f = 399$ kJ /kg $t_s = 95,2\ °C$

$h_b - h_e = 2365$

$h_b = 2365 + h_e = 2365 + 399$
$= 2764$ kJ/kg

$h_b = h_f + xh_{fg}$ at 2500 kPa $\therefore$ $2764 = 962 + 1839\,x$

$\therefore$ $x = 0,98$ (4)

6.3 Heat lost to moisturise = $M_m (h_s - h_f)$

$= 9 \times 0.04\ (2975 - 105)$

$= 1\ 033,2$ kJ/kg
(NB .1kg of H_2 requires 8 kg O_2 to form 9 kg H_2O) (3)

6.4 Heat lost to dry flue gas = m .Cp. Δt

$= (18 + 1 - 0,36)\ 1{,}045\ (250 - 25)$

$= 4382{,}7$ kJ/kg (3)

6.5

Heat supplied	Heat to		%
Mf x CV = 32500 kJ	Steam = 9(3010 −138)	= 25 848	79,53 %
	Moisture	= 1 033,2	3,18 %
	Dry flue gases	= 4 382,7	13,49 %
	Radiation	= 1 236,1	3,8 %
		32 500	100 %

(5)
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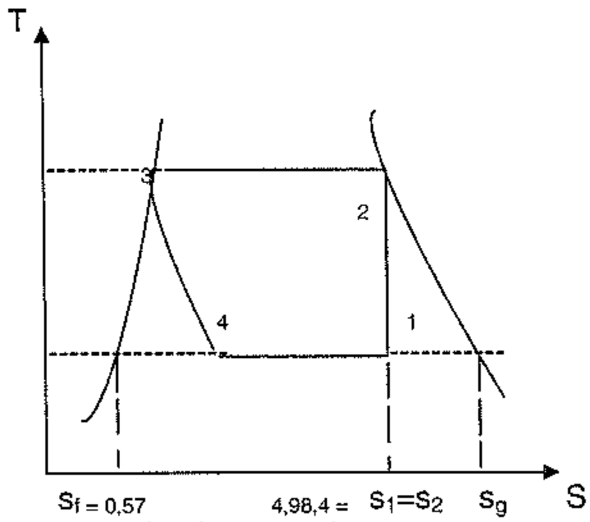
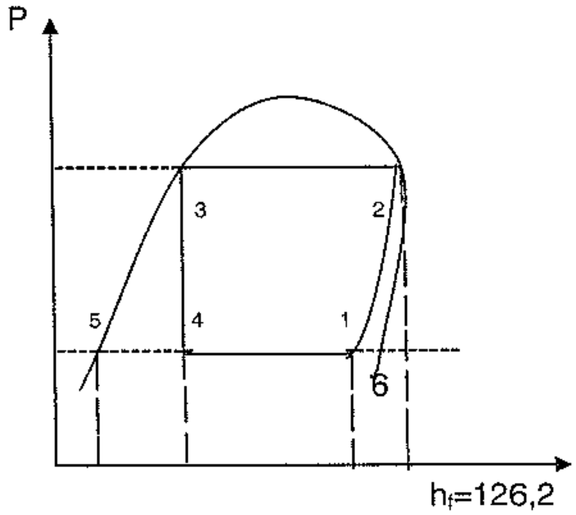
QUESTION 7

7.1





h_3=323,1 h_f h_2=1468,9 h (5)

7.2 7.2.1 $T_1 = T_4 = -12 + 273 = 261$ K

$T_2 = T_3 = 30 + 273 = 303$ K

From T – S diagram

$$q = \frac{S_1 - S_f}{S_g - S_f} = \frac{4{,}984 - 0{,}57}{5{,}504 - 0{,}57} = 0{,}895$$

From P – h diagram

$h_1 = h_f + q.h_{fg} = 126,\ 2 + 0{,}895 \times 1304,\ 3$

$= 1293,\ 55$ kJ/kg

$$\therefore \text{C.O.P} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{1293{,}55 - 323{,}1}{1468{,}9 - 1293{,}5} = 5{,}533$$ (7)

7.2.2 7.2.2 $Q_{\text{per kg of ice}} = hfg + m \times Cp \times \Delta t$

$= 327 + 1 \times 4{,}187 \times (25 - 0)$

$= 431{,}68$ kJ/kg

Refrigerating effect $= \frac{Q_{\text{per kg ice}} \times m}{t}$

$= \frac{431{,}68 \times 1000}{24 \times 60 \times 60}$

$= 4{,}996$ kJ/s

Work done $= \frac{\text{Refrigerating Effect}}{\text{C.O.P}}$

$= \frac{4{,}996}{5{,}333}$

$= 0{,}903$ kW (8)

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TOTAL: 100